

NSRR High Burnup Fuel Tests for RIAs and BWR Power Oscillations without Scram

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In order to examine high burnup fuel performance under reactivity-initiated accidents (RIAs) and under unstable power oscillation conditions arising during an anticipated transient without scram (ATWS) in boiling water reactors (BWRs), fuel irradiation tests were conducted with irradiated fuels under the simulated power transient conditions in the Nuclear Safety Research Reactor (NSRR).

In the RIA simulating tests of BWR fuels at a burnup of 61 GWd/tU, cladding failure occurred in tests at fuel enthalpies of 260 to 360J/g (62 to 86cal/g) during an early phase of the transients, while the cladding remained cool. Transient hoop strain measurements of the cladding in the early phase of the transients indicated small deformation below 0.4 % (**Fig. 1**), suggesting that the deformation was caused mainly by thermal expansion of the pellets. Hydride distribution in the BWR cladding was different from those observed in the PWR fuels failed in the earlier tests (**Fig. 2**), which likely contributed

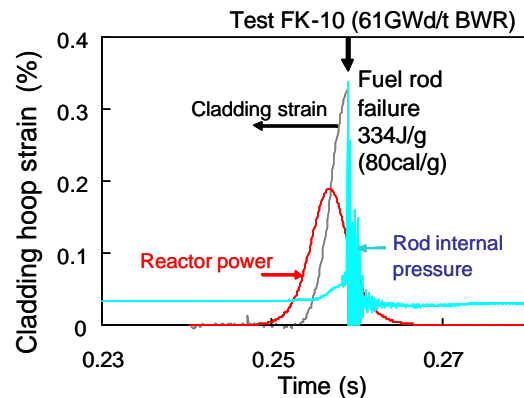
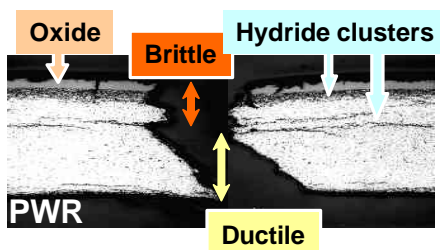
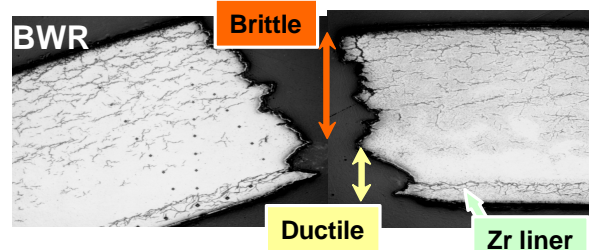


Fig. 1 Cladding deformation history measured in a RIA test with a high burnup BWR fuel rod. The rod failed at a fuel enthalpy of 80cal/g with cladding hoop strain below 0.4%.



PWR 50GWd/t (hydrogen: about 400ppm) failed at 250J/g(60cal/g)



BWR 61GWd/t (hydrogen: about 200ppm) failed at 292J/g(70cal/g)

Fig. 2 Comparison of PWR and BWR cladding cross sections failed in RIA tests. Hydrides in the BWR cladding were oriented more randomly.

to the BWR fuel failure at low hydrogen contents of about 150-200ppm. Transient fission gas release by the pulse irradiation was about 9.6 to 17% depending on the peak fuel enthalpy.

In the power oscillation tests, irradiated fuels at burnups of 56 and 25 GWd/tU were subjected to four and seven power oscillations, which peaked at 50 to 95 kW/m at intervals of 2 s. Peak fuel enthalpies were estimated to be 256 J/g (61 cal/g) and 368 J/g (88 cal/g) in the two tests. The power oscillation was simulated by quick withdrawal and insertion of six regulating rods of the NSRR. An example of the rod behavior under the transient condition is shown in **Fig. 3**. The cladding elongation increased as the power rose up, independent to the cladding temperature. The result suggested

that pellet-cladding mechanical interaction (PCMI) caused the cladding deformation in the test. The cladding deformation was comparable to those observed in the RIA tests at the same fuel enthalpy level up to 368 J/g (88 cal/g). Cladding axial deformation due to the PCMI was not enhanced due to the cyclic load.

Fission gas release, on the other hand, was considerably smaller than in the RIA tests, suggesting different release mechanisms between the two types of transients. **Figure 4** compares fission gas releases in the transient heating tests of high burnup BWR fuels. Fission gas release in test FK-11 with a BWR fuel at an estimated peak fuel enthalpy of 256 J/g (61 cal/g) was much smaller than that in a comparable RIA test FK-5 with a sibling fuel at a peak fuel enthalpy of 293 J/g (70 cal/g).

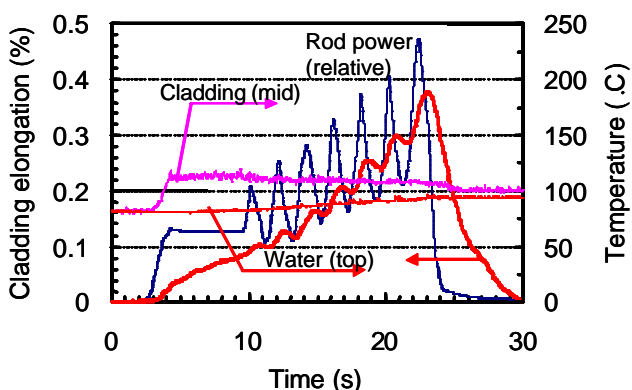


Fig. 3 Transient power, temperature and cladding deformation history measured in a power oscillation test with a fuel rod at a Burnup of 25 GWd/t. The rod was subjected to seven power oscillations at linear heat rates up to 95kW/m and at an estimated peak fuel enthalpy of 368 J/g (88 cal/g).

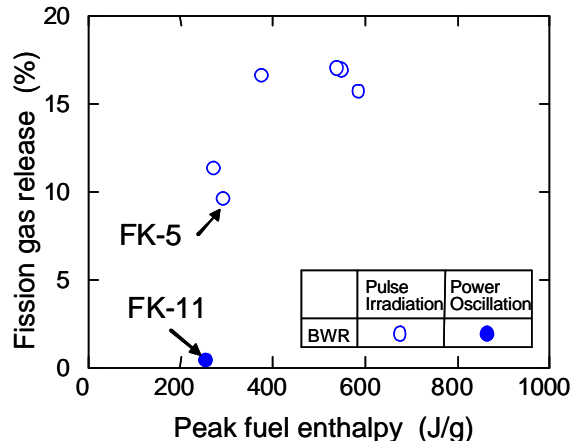


Fig. 4 Fission gas release observed in RIA and power oscillation tests of BWR fuel rods at burnups from 56 to 61 GWd/t as a function of peak fuel enthalpy.